SOLAR SYSTEM OCCULTATION SURVEY: URANUS, NEPTUNE & PLUTO

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Arnold R. Klemola

UCO/Lick Observatory, Board of Studies in Astronomy & Astrophysics
University of California, Santa Cruz, California 95064 U.S.A.

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1. INTRODUCTION

The great value of stellar occultations for learning about the bodies of the solar system since the 1970's is well documented. Observations of planetary occultations of the outer planets have led to the discovery of rings around Uranus and the ring 'arcs' around Neptune as well as knowledge about the shape of the planets. The Voyager 2 imaging, photopolarimeter and radio occultation experiments provided snapshot views of Uranus in 1986. However, future occultation measurements should play an important part in an ongoing program to monitor these complex systems. Additional occultation observations will aid in detailing the nature and extent of those parts of Neptune's ring system which are opaque enough to occult stars. For Pluto/Charon the occultations will refine the sizes and shapes of these bodies, as well as clarifying the nature of the rare atmosphere.

2. SURVEYS (LICK/SAO/MIT) PREVIOUS TO THIS PROJECT

Several earlier series of photographic plate searches were made for occultations using the Lick astrograph, in cooperation with Mink and others (SAO/MIT), covering the interval 1977–1991 for Uranus, 1978–1990 for Neptune, and 1985–1990 for Pluto/Charon. Searches for occultations by satellites of Uranus and Neptune were also made for the period 1983–1990. For details of this earlier work see introductions and references cited below in Klemola & Mink 1991, Mink, Klemola & Buie 1991.

3. PRESENT OCCULTATION SURVEYS

This paper extends the occultation search to 31 December 1999. It provides a variety of events from which observers may select those which can contribute to specific objectives.

3.1 Distribution of Work: Lick (Klemola) and SAO (Mink)

The surveys conducted for this project are composed of two distinct parts. The first part carried out at Lick by Klemola (NAGW-1525) consists of the photographic observations with the astrograph, initial coarse star selection around the trajectories of the three planets, precise rectangular coordinate measurements, and reductions for positions (right ascensions and declinations for equinox 1950). Approximate photovisual magnitudes were also derived for each candidate star (11780 stars for Uranus, 4818 stars for Neptune, and 6329 stars for Pluto/Charon).

The three resulting catalogs of occultation candidate stars were then transmitted to Douglas Mink (NAGW-1490) at SAO who proceeded with the second part of the project. The second part consisted of the merging of redundant measurements of stars appearing on overlapping Lick plates, the computation of *precise* planetary ephemerides to find dates for minimum angular separations from each candidate star. Those stars from the initial coarse Lick selection with large separations indicating no possible occultation were then dropped from the three catalogs. Also fainter stars were

omitted leaving short *refined* lists of possible candidates. The detailed circumstances for each possible occultation were then computed. These are the stars which appear in our two published papers: Klemola & Mink 1991 for Uranus and Neptune events and Mink, Klemola & Buie 1991 for Pluto/Charon events (with charts).

3.2 Survey Results for Uranus, Neptune, and Pluto

URANUS: A total of 76 occultation candidate stars were isolated. The brightest stars are SAO 189232 on 16 March 1996 and SAO 163583 on 10 April 1996. The areas of visibility for these events are small but cover major observatories. The occultation of SAO 163583, an M0 star, should be an especially good event in the infrared. In addition to these events, widely visible, near-central occultations occur on 8 July 1992, 13 July 1994, and 27 August 1998.

NEPTUNE: Neptune is emerging from the galactic plane into a much less dense region of stars, so there are few events in the 1990's. A total of only 18 stars possibly occulted by Neptune and/or its rings were isolated. Those Neptune events occurring on 18 July 1993 and 6 September 1996 stand out as the best planet occultations, with the best observability and the most central events. SAO 188797, on 29 November 1997, is the brightest star occulted, but the occultation is only visible from Western Australia and Southeast Asia. On 11 July 1992, 6 November 1997, and 22 March 1999, occultations by Neptune's ring arcs are possible. A further effort will be made to search for ring arc occultations by the fainter stars in our plate catalogs (note: we omitted our fainter stars in our two papers described here).

PLUTO/CHARON: For Pluto there are 32 candidate stars and for Charon 28 stars which may be occultated during this decade. There are three cases where the same star may be occulted by both Pluto and Charon (8 January 1995, 6 July 1995, and 26 September 1999). Among the Pluto events, good events include 1 March 1992, where the nominal track crosses Japan and New Zealand, 3 October 1993 visible in Australia, 17 April 1996, visible from eastern U.S. and Canary Islands, 9 July 1998, visible over Europe, Africa, and Atlantic Ocean, and 27 February 1999, visible over India. The favorable Charon events include 30 January 1992, visible in western U.S., 28 July 1996, visible either on east coast of U.S. or South America, and 1 February 1999, visible possibly in Australia or Japan.

It should be emphasized that all predicted events in these surveys should be refined during preceeding months and weeks by extensive "last-minute astrometry" to fix more precisely the track on the Earth's surface (some tracks may fall off and be unobservable).

3.3 Remaining Potential of Survey Catalogs

The initial wide-strip survey for candidate stars made at Lick was broad

enough to enclose the extreme elongations (in declination) of most of the satellites of Uranus and Neptune. So far only a small part of this material was used to find possible satellite occultations. In particular, Wasserman, Mink, and Klemola (IAUC No. 5243, 1991) found 7 close appulses of stars to Neptune I (Triton). However, much more work remains, apart from the present NASA grant, for the other satellites using the three initial catalogs generated by the present surveys (Uranus with 11780 stars, Neptune with 4818 stars, and Pluto with 6329 stars).

NOTE: The NASA Technical Officer for this Grant is Mr. James H. Dolvin, NASA, Washington. D.C., 20546.

PUBLICATIONS GENERATED BY THIS GRANT

Klemola, A.R. and Mink, D.J. (1991) Astron. J. 102, 389. "Occultations by Uranus and Neptune: 1991–1999"

ABSTRACT: The results of a photographic plate search are presented for stars as faint as $m_v = 14$ which may be occulted by Uranus or Neptune or their rings between 1 January 1991 and 31 December 1999. Circumstances for the closest approach of Uranus to 76 stars and Neptune to 18 stars are presented. Occultations by Neptune's ring "arcs" are predicted in 1992, 1997, and 1999.

Mink, D.J., Klemola, A.R., and Buie, M.W. (1991) Astron. J. 101, 2255. "Occultations by Pluto and Charon: 1990–1999"

ABSTRACT: The results of a photographic plate search for stars as faint as V = 16 which may be occulted by Pluto or Charon between 1 January 1990 and 31 December 1999 are presented. Circumstances for the closest approach of Pluto to 32 stars and Charon to 28 stars are presented. Photometric information is given for some of the brightest stars found in the search of the *Space Telescope Guide Star Catalog* for Pluto occultations. Finding charts from Space Telescope Guide Star plate are provided for some of the best events. The brightest star (V = 12.7) may be occulted by both Pluto and Charon on 26 September 1999.

Wasserman, L.H., Mink, D., and Klemola, A.R. (1991) IAUC No. 5243. "Neptune I (Triton)."

This note reports seven possible occultations by the satellite Triton, of which two are described as events on 9 July 1991 and 4 August 1991. All seven occultations occur with Neptune high in the sky and observable at sites populated by major telescopes.